Hyperon-Proton Scattering Experiments at J-PARC [L07]

- ***KEK-PS experiments***
- ***Experiments at J-PARC***
- ***... seems to be a long way towards a proposal***

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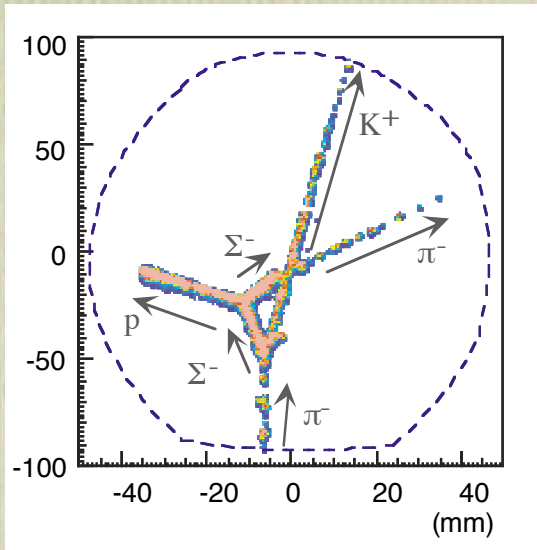
Hyperon-proton scatterings

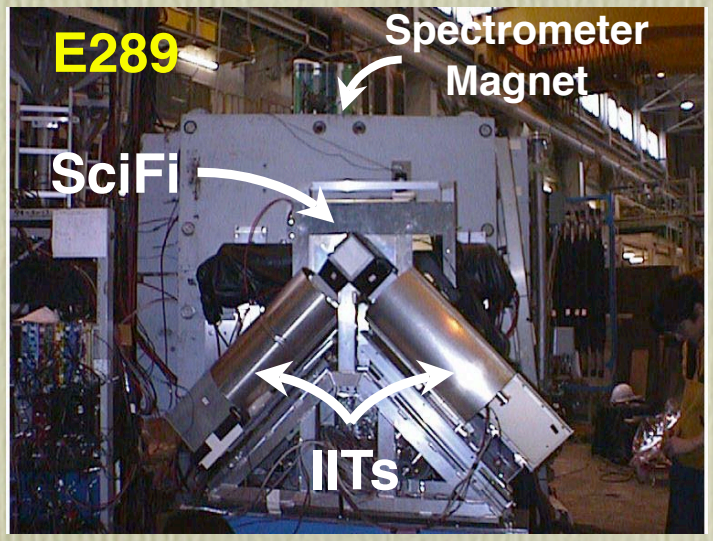
	cτ [cm]	production reaction	(σ[μb] @P[GeV/c])	outgoing particle	Y-p scattering	scattered particle		decay mode	α	decay particles	
Λ	7.89	$\pi^- p \to K^0 \Lambda$	(700 @1.0)	$\pi^+\pi^-$	**Λp → Λp**	p	Λ	→ pπ⁻	0.642	p, π⁻	★
		$K^- p \to \pi^0 \Lambda$	(3500@0.9)	2γ				→ nπ⁰	0.65	n, 2γ	
					→ Σ⁰p	p	Σ^0	→ Λγ		p, π⁻, γ	★
										n, 2γ, γ	
Σ^+	2.396	$\pi^+ p \to K^+\Sigma^+$	(500 @1.6)	K^+	**Σ⁺p → Σ⁺p**	p	Σ^+	→ pπ⁰	−0.980	p, 2γ	★
		$K^- p \to \pi^-\Sigma^+$	(1500@1.2)	π^-				→ nπ⁺	0.068	n, π⁺	★
Σ^-	4.434	$\pi^- p \to K^+\Sigma^-$	(250 @1.5)	K^+	**Σ⁻p → Σ⁻p**	p	Σ^-	→ nπ⁻	−0.068	n, π⁻	★
		$K^- p \to \pi^+\Sigma^-$	(1500@1.0)	π^+	**→ Λn**	n	Λ	→ pπ⁻	0.642	p, π⁻	★
								→ nπ⁰	0.65	n, 2γ	
					→ Σ⁰n	n	Σ^0	→ Λγ		p, π⁻, γ	
										n, 2γ, γ	
Σ^0	2.22×10^{-9}										
Ξ^0	8.71	$K^- p \to K^0\Xi^0$	(90 @1.6)	$\pi^+\pi^-$	**Ξ⁰p → Ξ⁰p**	p	Ξ^0	→ Λπ⁰	−0.411	p, π⁻, 2γ	
										n, 2γ, 2γ	
Ξ^-	4.91	$K^- p \to K^+\Xi^-$	(160 @1.6)	K^+	**Ξ⁻p → Ξ⁻p**	p	Ξ^-	→ Λπ⁻	−0.456	p, π⁻, π⁻	★
										n, 2γ, π⁻	
					→ ΛΛ	Λ	Λ	→ pπ⁻	0.642	p, π⁻, p, π⁻	★
								→ nπ⁰	0.65	p, π⁻, n, 2γ	
					→ Ξ⁰n	n	Ξ^0	→ Λπ⁰	−0.411	p, π⁻, 2γ	
										n, 2γ, 2γ	



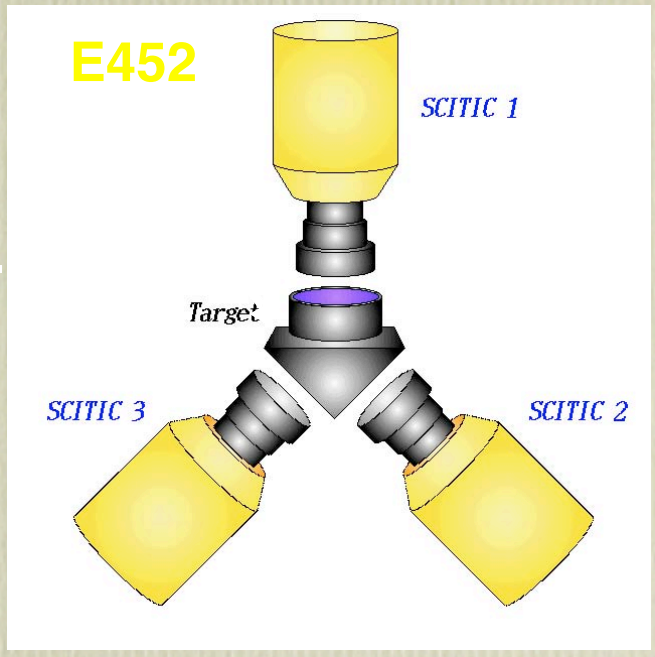
Yp scatt. at 12 GeV KEK-PS

– E251, E289 & E452 : Setup –

Scintillating Fiber (or Liquid Scintillator) with IIT-CCD Camera triggered by Spectrometer system



Liq.



Incident beam rate ≤ 10^5 Hz

← should be improved

Yp scatt. at 12 GeV KEK-PS

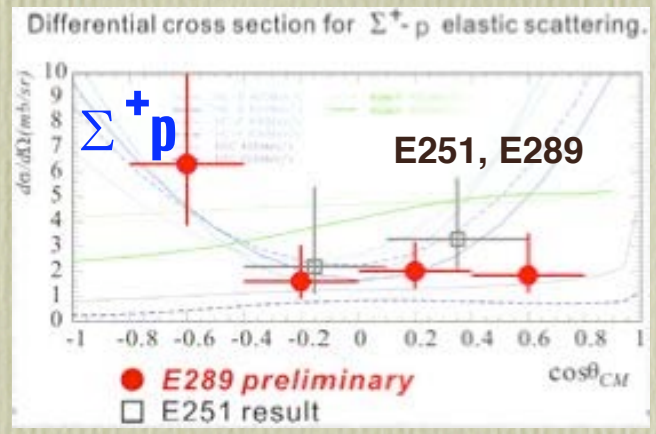
– E251, E289 & E452 : Yeild –

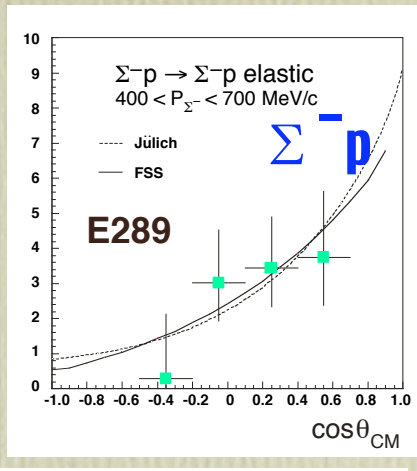
	E251	E289		E452
Proposed	1991/July	1992/November		1999/Oct
Approved	1991/July	1995/July		2000/July
Beam Time	92/Feb–Dec	95/Nov–97/Feb		00/Dec–02/Mar
Target	SCIFI	SCIFI		Liq.Scinti.
Beams	$4.1\times10^{10}\pi^+$	$5.0\times10^{10}\pi^+$	$8.6\times10^{10}\pi^-$	$8.4\times10^{10}\pi^+$
Hyperons	$5.7\times10^{4}\,\Sigma^+$	$2.7\times10^{5}\,\Sigma^+$	$1.8\times10^{5}\,\Sigma^-$	$\sim10^{5}\,\Sigma^+$
Yp	$11\ \Sigma^+p$	$\sim 44\ \Sigma^+p$	$30\ \Sigma^-p$	$\sim 160\ \Sigma^+p$

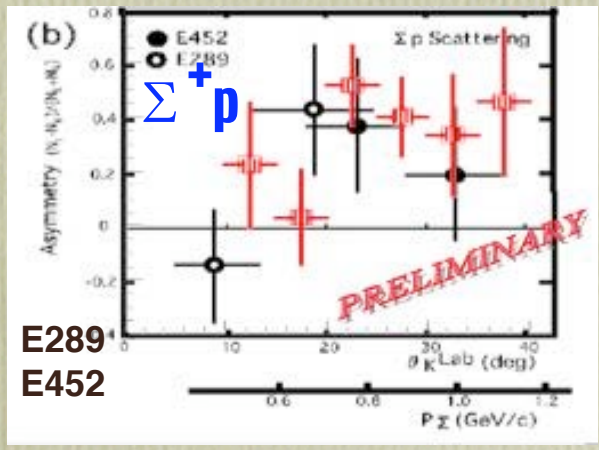
E452 is in analysis

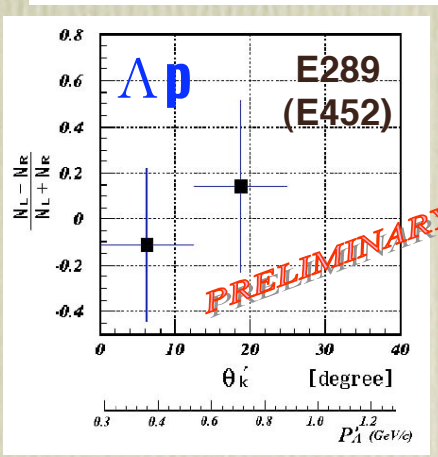
Yp scatt. at 12 GeV KEK-PS

– E251, E289 & E452 :Results –







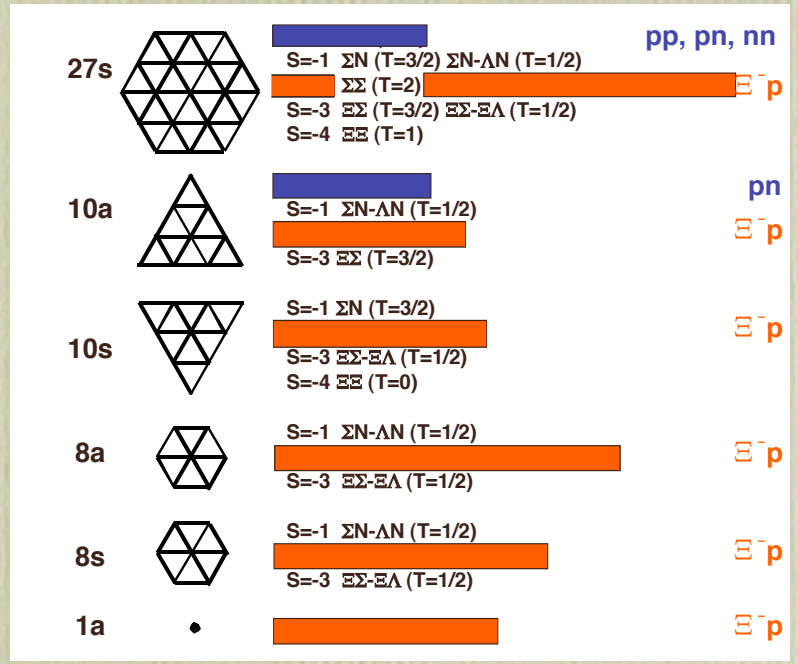


Improvements in instrumentation is impressive.
Accuracy, however, was too low to help decide...

— from Report on KEK-PS Review 2000 for E251 & E289

Experimental Objectives at J-PARC

☑ *S= - 2*



☑ *Anti-symmetric spin-orbit* ⟵ … better to wait for E452 results

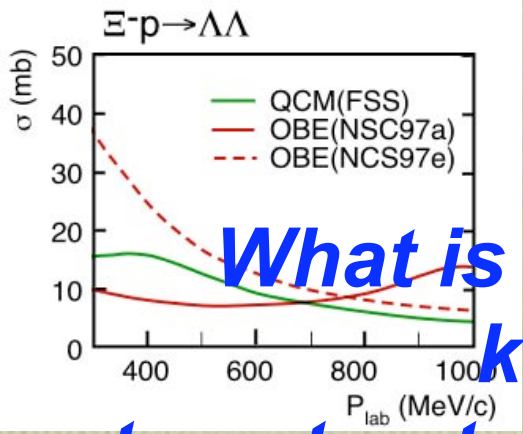
$$M = a + c(\sigma_n^1 + \sigma_n^2) + b(\sigma_n^1 - \sigma_n^2) + m\sigma_n^1\sigma_n^2 + g(\sigma_P^1\sigma_P^2 + \sigma_K^1\sigma_K^2) + h(\sigma_P^1\sigma_P^2 - \sigma_K^1\sigma_K^2)$$

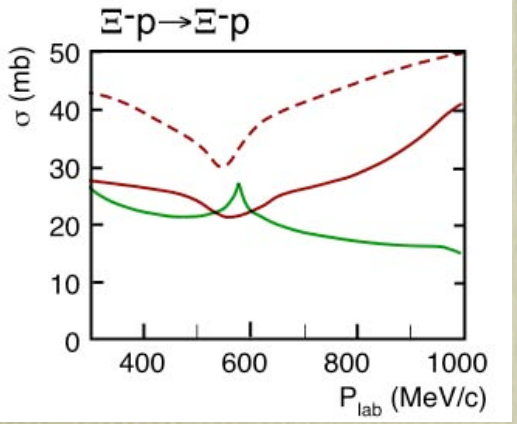
$$I_0 P_y = 1/4\ \mathrm{Tr}(MM^\dagger \sigma_n^1) = 2\,\mathrm{Re}[(a+m)c^* + (a-m)b^*]$$

$$(I_0 A_y^T = 1/4\ \mathrm{Tr}(M\sigma_n^2 M^\dagger) = 2\,\mathrm{Re}[(a+m)c^* - (a-m)b^*])$$

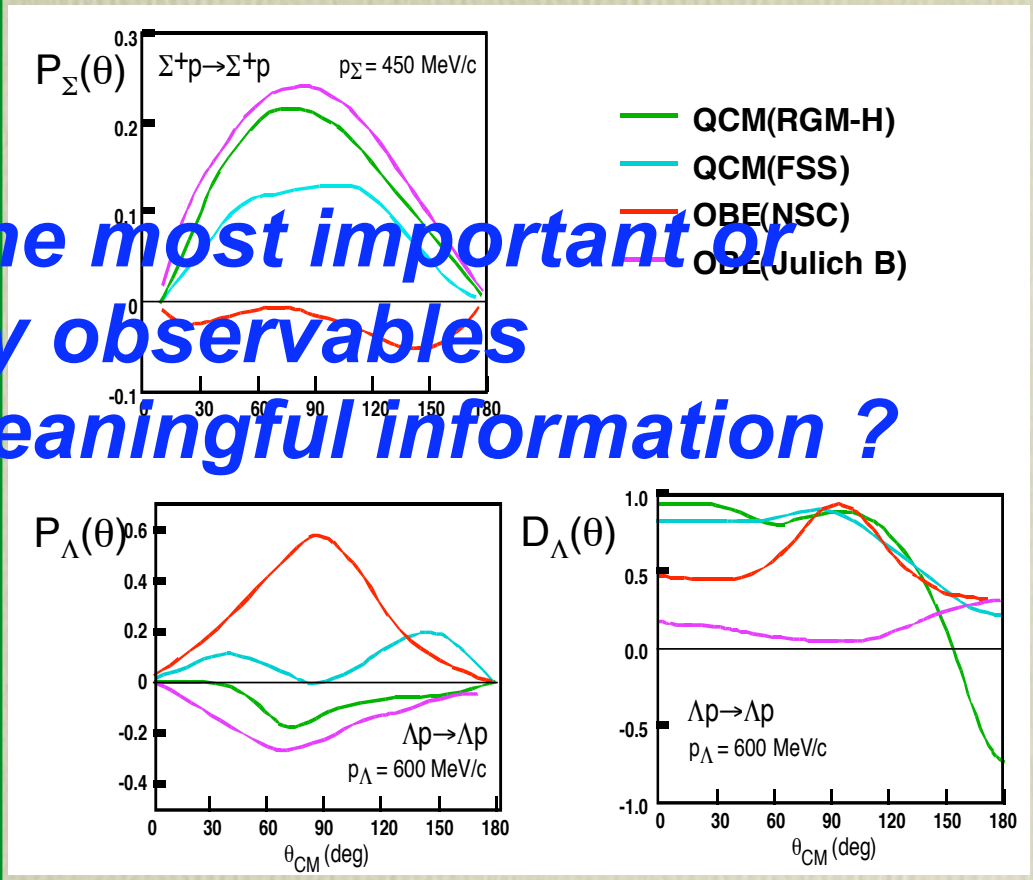
Calculation by Models
– what is a key (physics issue) ? –

S=-2
$\Xi^-p \rightarrow \Lambda\Lambda$, $\Xi^-p \rightarrow \Xi^-p$



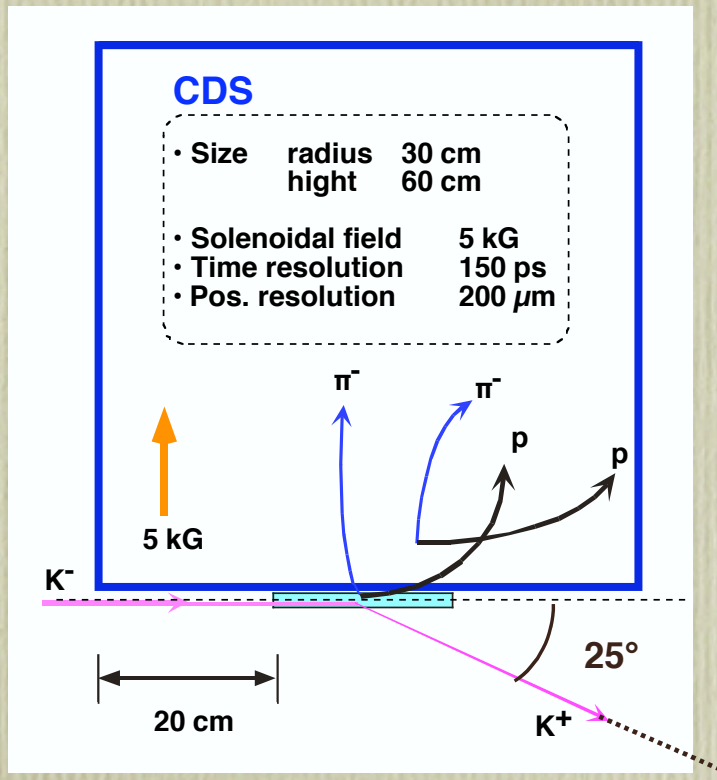


Polarization observables
(≈ Anti-symmetric spin-orbit)



What is the most important or key observables to extract meaningful information ?

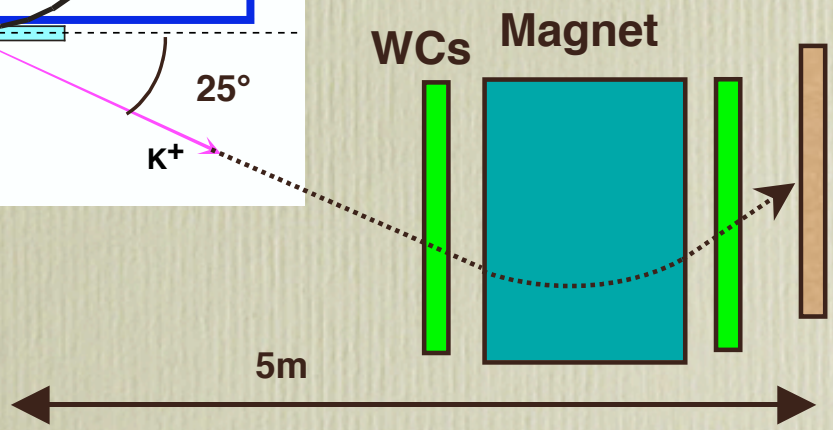
$\Xi^- p$ scattering : a method



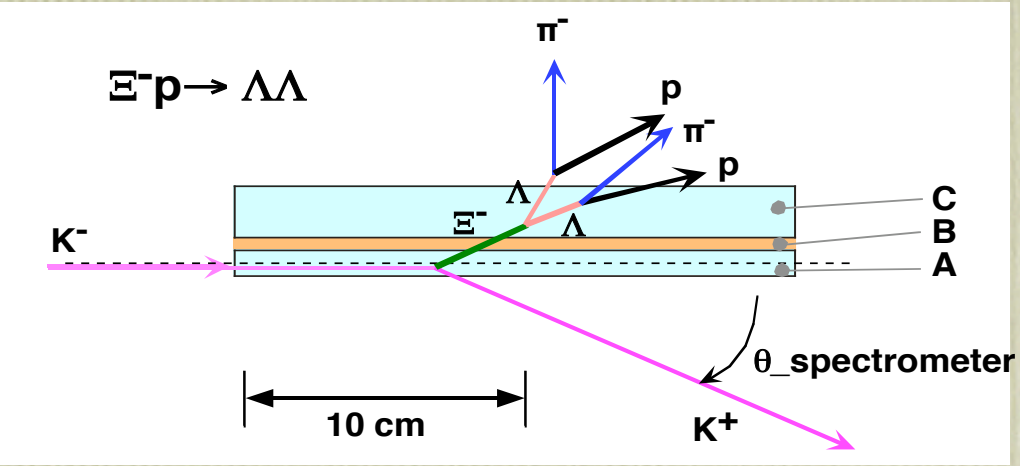
$K^- p \rightarrow K^+ \Xi^-$

$\Xi^- p \rightarrow \Xi^- p$
$\hookrightarrow \Lambda\pi^-$
$\hookrightarrow p\pi^-$

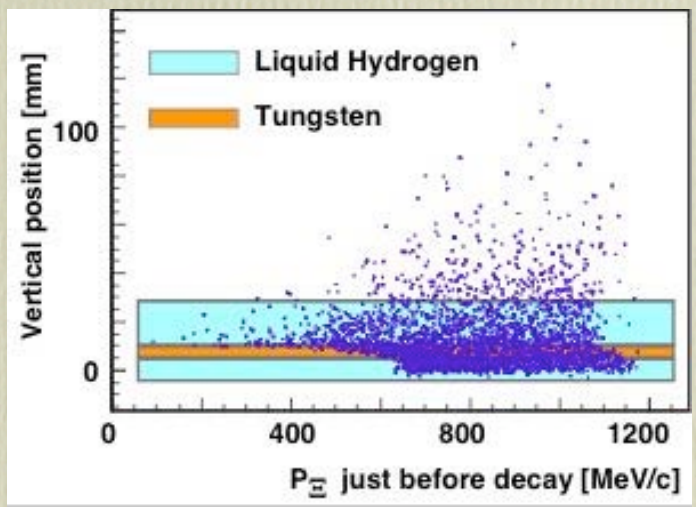
$\Xi^- p \rightarrow \Lambda\Lambda$
$\hookrightarrow p\pi^-$
$\hookrightarrow p\pi^-$



$\Xi^- p$ scattering : target region

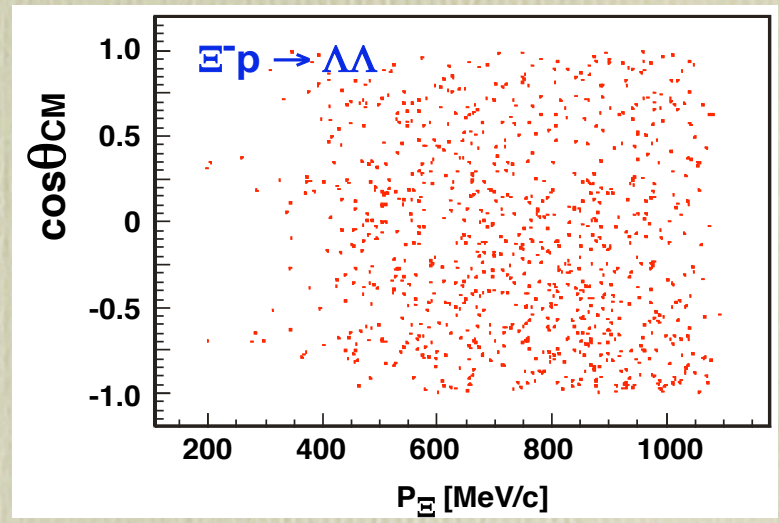


- Target 5 cm wide × 20 cm long
  - A: production 1 cm Liq. Hydrogen
  - B: degrader 0.5 cm Tungsten
  - C: scattering 2 cm Liq. Hydrogen
- K^+ spectrometer
  - θ_spectrometer ~ 25° at center
- K^- beam (assumption @ LOI)
  - Intensity 10^7 K^-/sec
  - Momentum 1.7 GeV/c
  - Size σ_horizontal 15 mm
  - σ_vertical 1 mm



$\Xi^- p$ scattering : a simulation

• K^- intensity	$[s^{-1}]$	10^7
• Number of Hydrogen	[/cm2]	8.5×10^{23}
• Spectrometer	[deg]	25
• Spectrometer TOF	[m]	5
• Trigger rate (K^+)	$[s^{-1}]$	11
• Momentum of Ξ^-	[MeV/c]	300 - 1100



		$\Xi^- p \rightarrow \Xi^- p$	$\Xi^- p \rightarrow \Lambda\Lambda$
• reaction rate	$[s^{-1}]$	0.009	0.0043
• 100 days		78000	37000
• Detectable number		2300	550

$\Sigma^+ p$ & Λp scattering : a method

Similar as E289, BUT R&D needed for ...

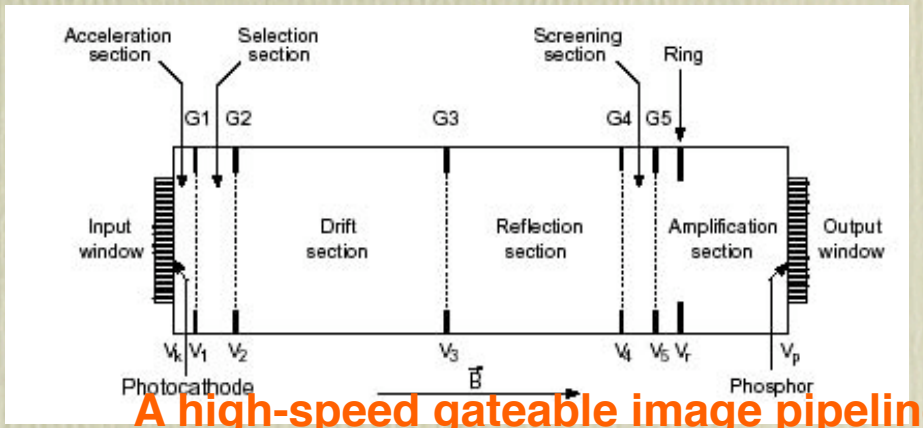
- Imaging device

  Improve "rate limit"

  10^5 Hz

  ↓

  10^7 Hz ⟺



A high-speed gateable image pipeline

By Berkovski et. al. NIM A380(1996)537

- Online trigger rate
  - – (π, K) cut
  - – Image brightness cut

Assuming success of these R&D

an estimation from KEK-E289

~ 4000 $\Sigma^+ p$ elastic @ 10^7 π^+/sec in 10 days

Requests & Works

for $\Xi^- p$ (S= -2), $\Sigma^+ p$ & Λp (Polarization obs.)

——— reasonably doable at J-PARC

Requests

- *Separated beam line around 1.5 - 1.8 GeV/c*
- *K^- intensity 10^7/sec with K/p > 1*
- *Liquid hydrogen facility*

Works

- *Realistic Optimization of Setup*
- *Background estimation (physical & instrumental)*
- *Fast imaging device*
- *Trigger consideration*

NPFC Comments on L07

The committee is concerned that the statistical accuracy of the proposed measurement would not be sufficiently precise to extract meaningful information on the relevant physics. We recommend that the group consider formulating an experimental approach that significantly enhances their detection efficiency. We also recommend that they determine what sort of data quality is required to address the physics issues likely to be of greatest interest when this experiment is carried out, which realistically would be 5-7 years in the future.

The committee also expects the proponents to examine the following technical issues in detail in a full proposal. The beam halo will yield serious backgrounds requiring that appropriate measures be taken. Because the proponents have so far employed some visual imaging devices as a target-detector system in their experiments, a fast imaging device might be another option instead of the drift chamber. We expect the group to design these detectors in detail and to determine their pros and cons relative to other approaches.

The committee encourages the proponents to develop a full proposal that aims at Phase 1 running.